A mixed model approach to modelling global habitat suitability and invasion risk of the American bullfrog

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Invasive Species

- Species that have a negative impact on native flora and fauna
- Global threat to biodiversity and threatened/endemic species
- May be invasive through competition, predation, environmental alteration, etc.
- **Difficult to predict where a species may become invasive if introduced**

Objectives

- **Use mixed modelling to determine likely range or invasible areas**
- **Model potential dispersal pathways**

Background: American bullfrog

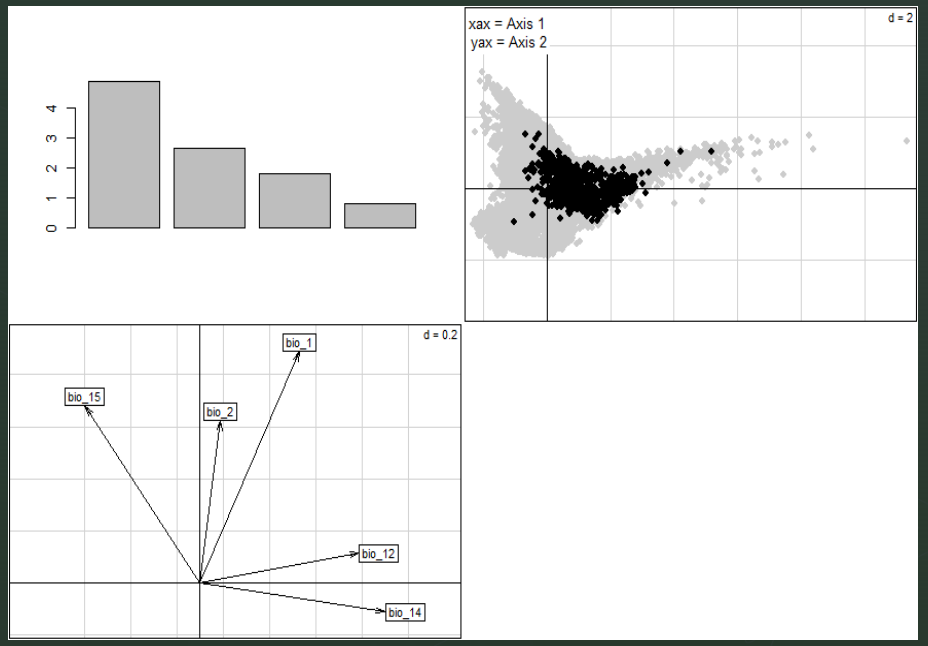
- *Lithobates catesbeianus*
- Native to eastern United States
- Introduced to ~30 countries in Europe, South America, and Asia
- Invasive through competition, predation, and disease transmission

Modelling Methods

- Ecological Niche Factor Analysis (ENFA)
- Random Forest

Ecological Niche Factor Analysis (ENFA)

- Transforms data into a PCA with ecologically meaningful axes
- Clusters points along axes, then projects to whole dataset
- Identifies niche breadth



Right: Example ENFA graphs

Random Forest

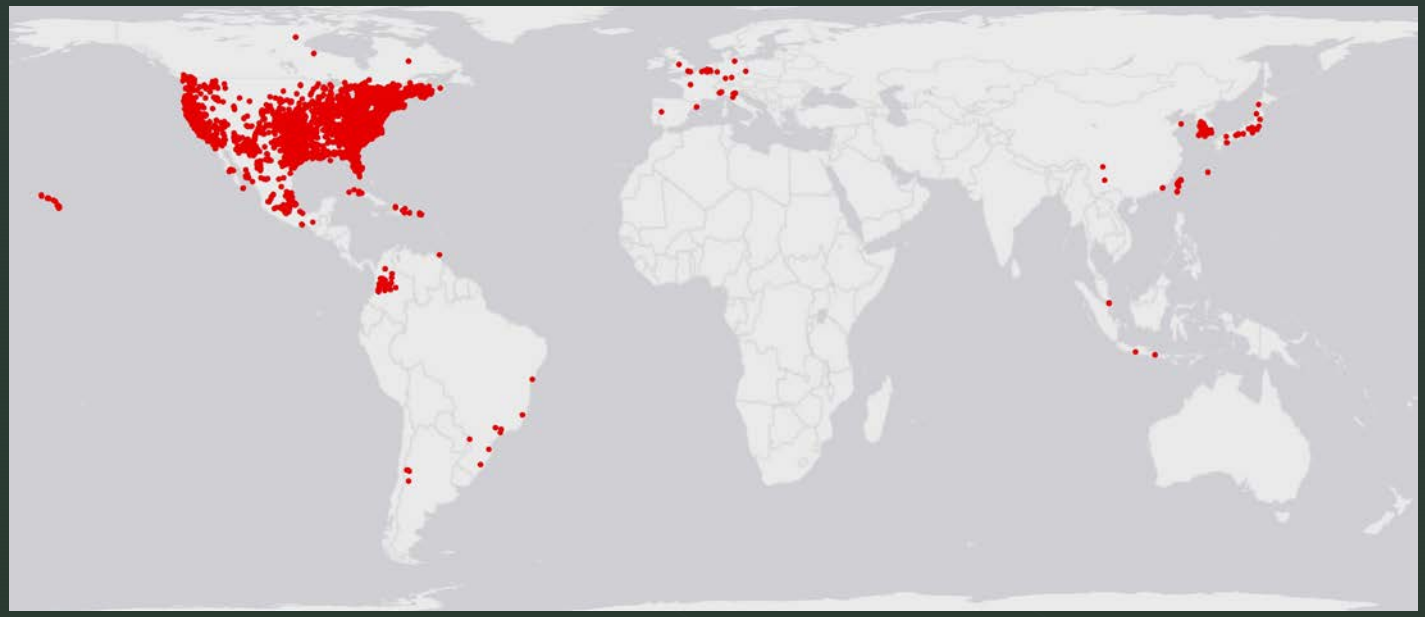
- Machine-learning method using regression trees
- Wide variety of application in the literature
- Very accurate modelling technique
- May under-represent areas that could be suitable but where the species is not currently found

Variables

Bioclimatic

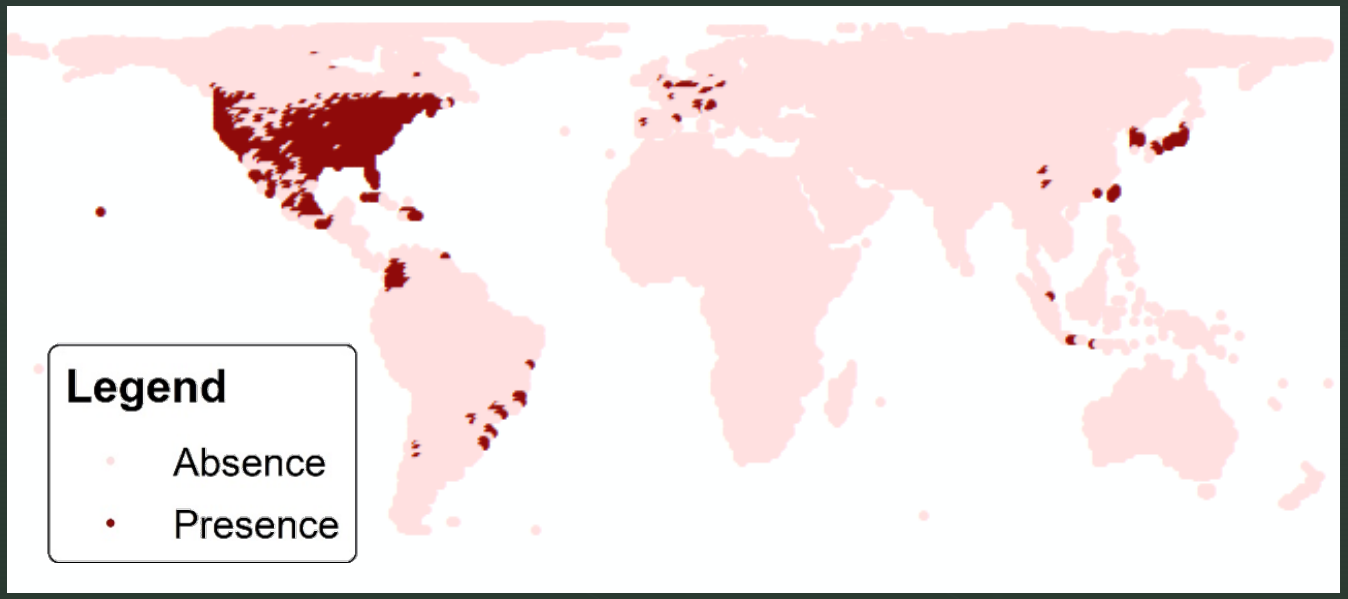
- Averaged temperature and total precipitation
- Minimum and maximum temperature and precipitation
- Seasonality and variation
- Included based on low multicolinearity

Data: Observation Points



Occurrences downloaded from GBIF
(Global Biodiversity Information Facility)

Observations to Presence-Pseudo-absence Data

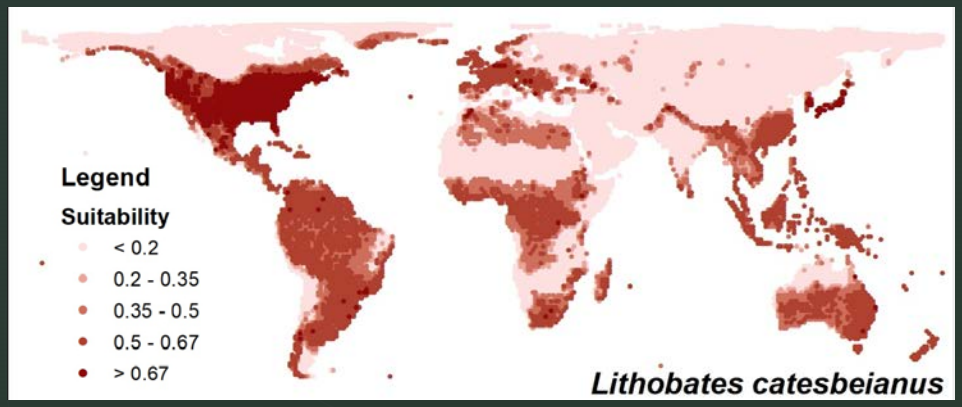


Occurrences converted to presence-pseudo-absence on global grid at 1 decimal degree resolution (reduces sample bias)

ENFA Result

Ecological Niche Factor Analysis result coded to binary

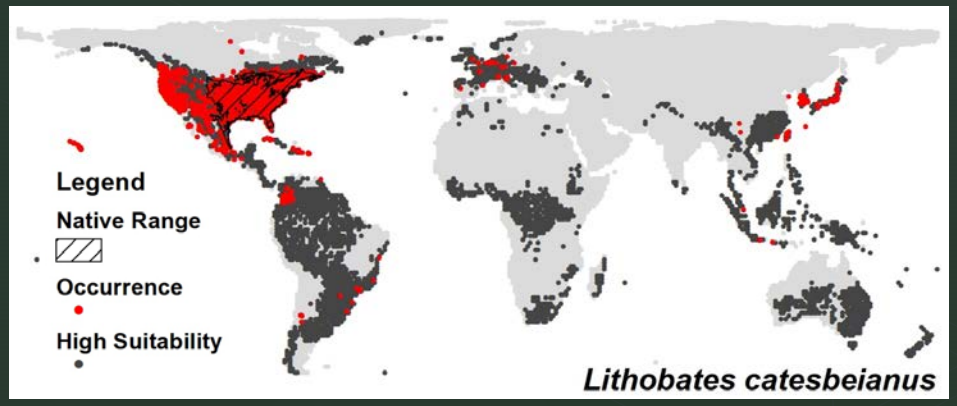
Results: Global Invasion Risk



Climate habitat suitability index

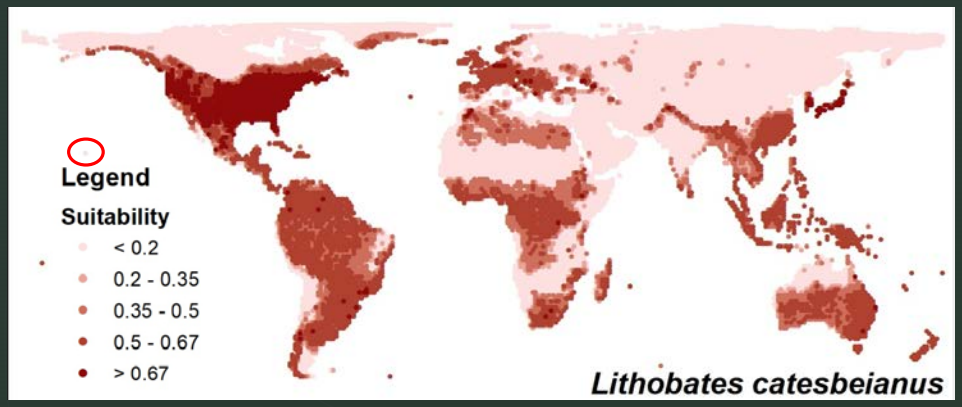
94.2% of occurrences located within 1 dd of “high suitability” points

AUC = 0.9527

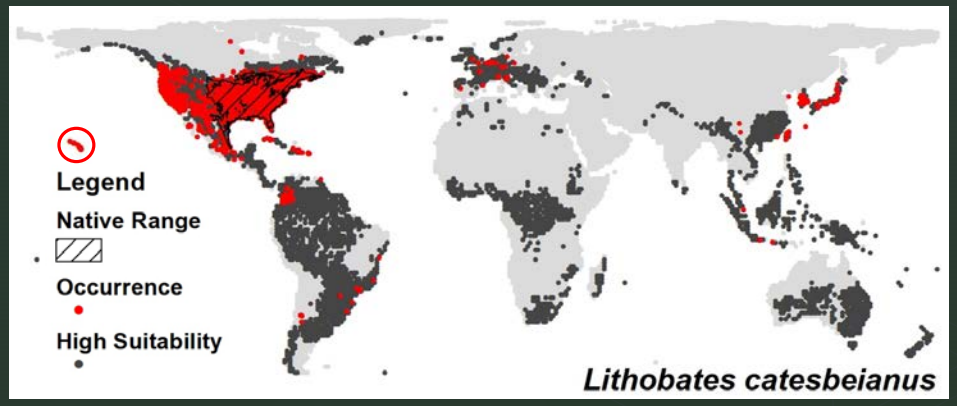


Current Range and Invasion Risk

Results: Global Invasion Risk



Climate habitat suitability index



Current Range and Invasion Risk

Impact on Korean ecosystems

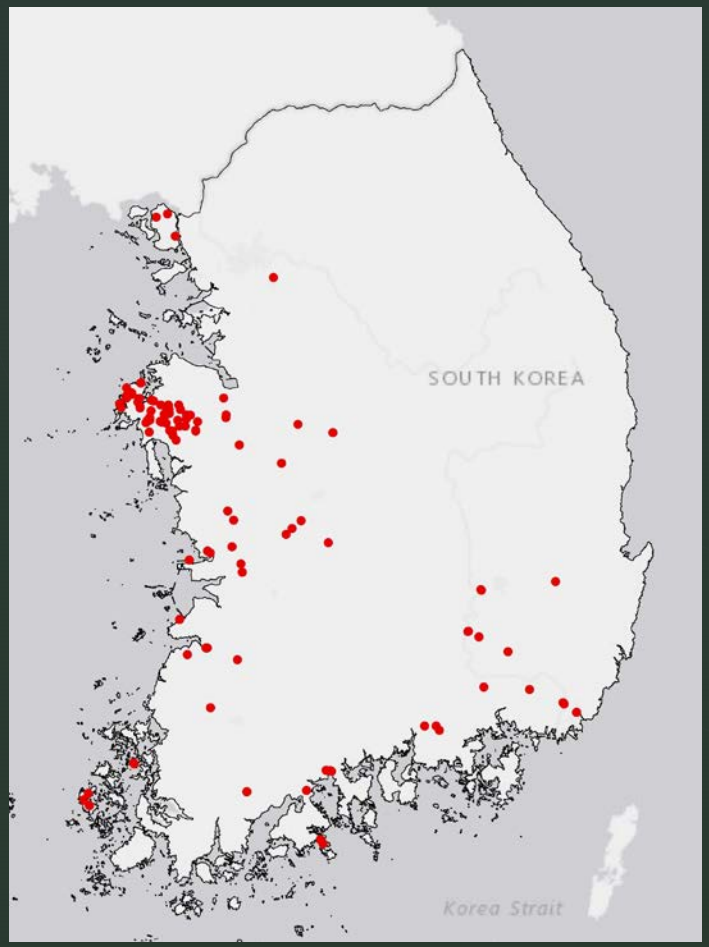
- Introduced through pet and food trade
- Predate on native frog species, including endangered Suweon treefrog (*Hyla suweonensis*, right)
- Competition for prey with some species
- Carriers for Bd

Modelling Methods

Local (Countrywide)

- Ecological Niche Factor Analysis (ENFA)
- Random Forest
- Generalized Logistic Model (GLM)
- Habitat connectivity (Linkage Mapper)

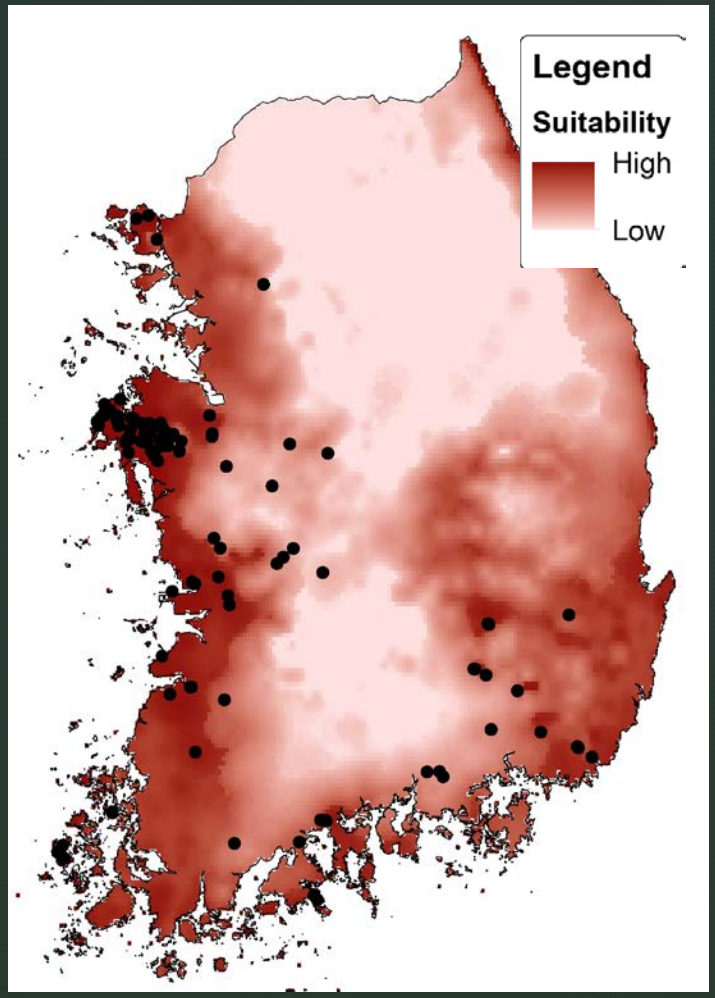
Observations in South Korea



- 199 occurrences from GBIF
- Converted to grid resolution of 0.05 decimal degrees

Results: ENFA and Random Forest in South Korea

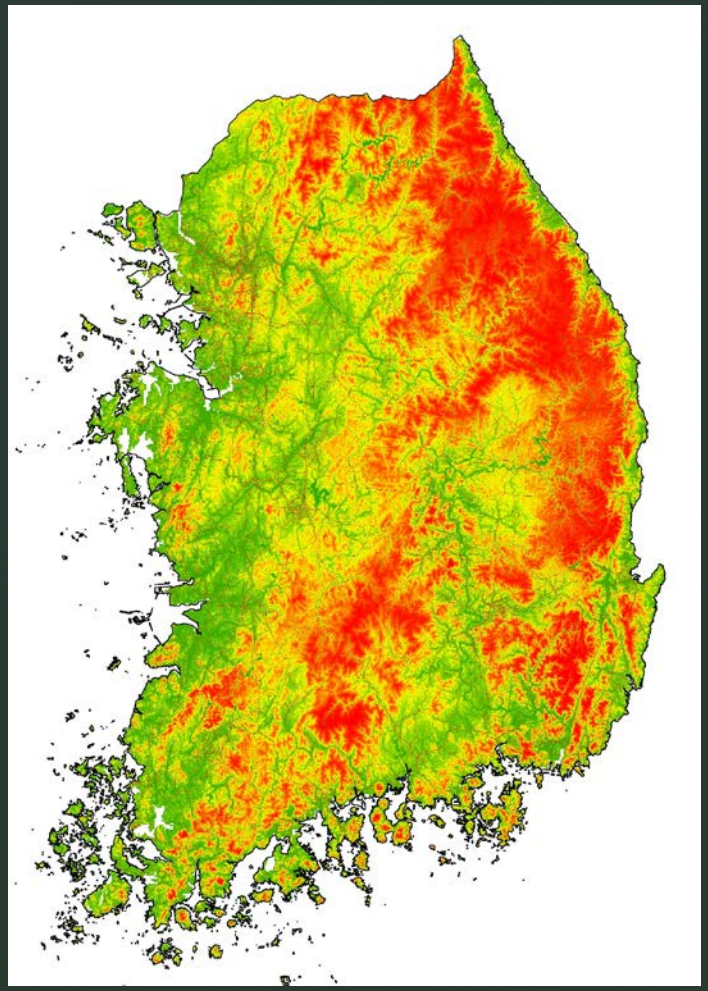
- High suitability in western and southeastern lowlands of South Korea
- 20,775 km^2 with > 0.5 suitability index, ~20% of South Korean land area
- Darker areas of high suitability include large portion of occurrence points
- 70% of occurrences located in > 0.5 suitability
- 95% of occurrences located in > 0.2 suitability



Generalized Logistic Model (GLM)

- Multivariate modelling approach
- Basic model for determining variable importance
- Works well with binary (presence-absence) data
- Included elevation, topographic wetness, soil/vegetation moisture (tasseled-cap wetness)

Dispersal Resistance



- GLM used to model terrain suitability
- Elevation, topographic wetness, surface moisture
- Inverted to represent resistance to dispersal

Left: Green represents low dispersal resistance, red represents high resistance

Corridor Mapping: Linkage Mapper

Habitat Cores

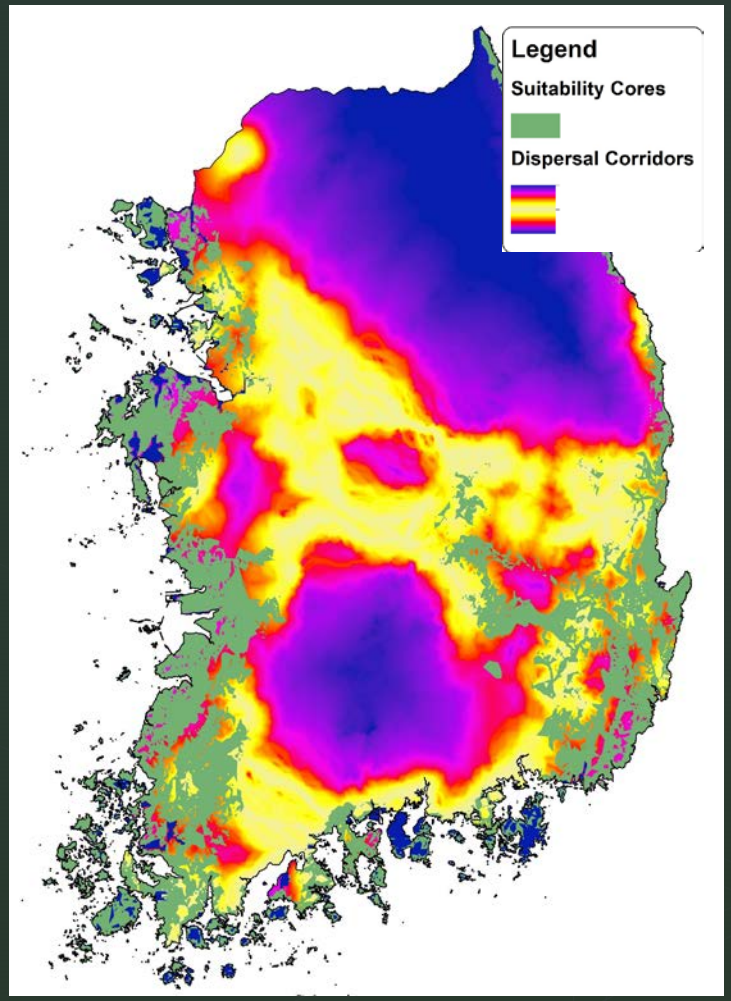
- Areas with > 0.5 bioclimatic suitability

Resistance

- Elevation
- Topographic Wetness
- Soil/vegetation moisture

Least-Cost Corridors

- Linkage Mapper incorporating climate suitability cores (green) and terrain resistance
- Coastal pathway
- Northwest to southeast pathways



Conclusions

- Distance-based models can be combined with machine-learning methods to help predict likely invasible areas
- This method can be used on both global and local scales
- Results from this modelling can inform where to anticipate a species will become invasive if introduced

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